CERES Aqua Edition2B SSF Surface Fluxes - Accuracy and Validation

One of the principal objectives for the CERES data products is to provide improved estimates of surface fluxes (net and downward) for shortwave (SW) and longwave (LW) radiation. To achieve this objective, considerable effort has been focused upon obtaining consistent fluxes at the surface, within the atmosphere, and at the top of the atmosphere, all of which are produced as part of the CERES CRS data product using the SSF as input data. Validated CRS surface fluxes, however, are just now becoming available. Thus, a second effort was initiated which uses much simpler algorithms either:

- to directly tie surface fluxes to broadband CERES TOA fluxes such as in Li et al. (1993) and Darnell et al. (1992) for SW fluxes, and Inamdar and Ramanathan (1997) for clear-sky LW surface fluxes.
- or to use simple radiative parameterizations (Gupta 1989 and Gupta, Darnell, and Wilber 1992) to estimate surface fluxes, especially for the case of surface downward LW fluxes which are effectively decoupled from the TOA fluxes for cloudy sky conditions.

Consequently, these simpler SSF surface flux parameterizations are more comparable to results used in past analyses of surface radiation data sets based on ERBE or geostationary data. In general, however, they are not expected to be as precise as the CERES CRS surface fluxes, though they do represent an independent method to get to the more difficult surface flux estimates.

The CERES SSF data product provides 4 surface flux algorithm results:

1. Shortwave Flux Model A, Daytime only, Clear-sky only
   - Net surface fluxes use Li et al. (1993).
   - Downward surface fluxes use Li et al. (1993) for net and Li and Garand (1994) for surface albedo.
2. Shortwave Flux Model B, Daytime only, Clear and All-sky
   - Net and downward surface fluxes use the Langley Parameterized Shortwave Algorithm (LPSA) (Darnell et al. 1992; Gupta et al. 2001).
3. Longwave Flux Model A, Daytime and Nighttime, Clear-sky only
   - Net and downward surface fluxes uses Inamdar and Ramanathan (1997).
4. Longwave Flux Model B, Daytime and Nighttime, Clear and All-sky
   - Net and downward surface fluxes use the Langley Parameterized Longwave Algorithm (LPLA) (Gupta 1989 and Gupta, Darnell, and Wilber 1992).

For Aqua surface fluxes, clear-sky conditions are defined for CERES footprints with an imager determined cloud cover percentage less than 0.1%. Thus, to be consistent with the angular distribution models, our validation effort has also taken clear-sky to be defined as a CERES footprint with an imager determined cloud cover percentage less than 0.1%. The SSF surface fluxes are being validated using both theoretical analyses and simultaneous matching of satellite data to a range of surface sites. Preliminary results are discussed in the sections which follow.

The CERES SSF surface flux estimates are derived using the Aqua data starting with July 2002 and running through March 2005. The coincident surface fluxes are nominally gathered from the Atmospheric Radiation Measurement (ARM) networks which include the Southern Great Plains (SGP), Tropical Western Pacific (TWP) and North Slope Alaska (NSA) sites, the Global Monitoring Division, Earth System Research Laboratory (GMD/ESRL) [formerly known as the Climate Modeling and Diagnostic Laboratory (CMDL)] network, the Baseline Surface Radiation Network (BSRN) and the Surface Radiation (SURFRAD) network. Unless otherwise noted, surface site fluxes are 1 minute averages and are compared to the CERES footprint which includes the surface site.

The validation results reported in this data quality statement compare Aqua Edition2B.

Clear-sky Shortwave Downward Flux Validation: Models A and B

For the shortwave, two models have been used to produce the surface fluxes. Both of these shortwave models are part of our validation effort; however, Model A currently produces fluxes only for clear-sky conditions while Model B produces fluxes for both clear and all-sky conditions. When the column ozone exceeds 500 DU, Model B net and downward SW surface flux values are not computed. Instead they are set to the CERES fill value.

Validation studies of the TRMM Edition 2B surface fluxes demonstrated that shortwave Model A overestimated surface insolation at the ARM Central Facility by approximately 30 W m^{-2}. Considering that such biases were not observed for pristine high-latitude surface sites, it was hypothesized that the effects of aerosols could be the cause. Thus, an aerosol correction factor based on the Masuda et al. (1995) method and using the GFDL climatological aerosols (Haywood et al., 1999) was incorporated into shortwave Model A. The use of the Masuda et al. (1995) method with the GFDL climatological aerosols was shown earlier to produce a significant improvement to shortwave Model A. Further improvements in the estimation of the contribution of aerosols have been achieved by replacing the GFDL climatological aerosol product with a five year monthly climatology of the aerosol optical depths at 0.55 microns based upon the Model of Atmospheric Transport and Chemistry (MATCH) aerosol product (Rasch et al., 1997 and Collins et al., 2001) developed by the National Center for Atmospheric Research (NCAR). The MATCH climatological aerosol data product was incorporated into the CERES SSF Model A processing with Aqua Edition2A.

At the same time SW Model A was upgraded to use the climatological MATCH aerosol optical depths, we also replaced the WCP-55 aerosol maps used by Model B with the broadband monthly climatological aerosol properties based upon the MATCH and OPAC (Optical Properties of Aerosols and Clouds) data products. For the OPAC data the reader should refer to Hess et al. (1998). We further upgraded SW Model B by replacing the monthly climatological ERBE clear-sky TOA albedos with the corresponding values derived from 46 months of Terra data. Unlike SW Model A, however, these changes resulted in large positive biases for SW Model B. A thorough investigation of SW Model B revealed a complex coupling among the various parameters in SW Model B. Since untangling this complex coupling is expected to require extensive work, we decided that for Aqua Edition2B, the best course of action was to return SW Model B to the version previously used in Aqua Edition1B.

In contrast to earlier versions of the SSF Data Quality Summaries, Terra 2B, Aqua 1B and later versions (including Aqua 2A) group together surface sites with similar characteristics: Continental, Desert, Coastal, Island and Polar, rather than grouping together surface sites from a single source. This has allowed for a better interpretation of those surface and climatological types that have proven to be the most problematic.

The following tables for the clear-sky cases compare shortwave Models A and B to the surface measured fluxes. Biases are defined to be CERES derived surface fluxes minus surface measured fluxes. Substituting the MATCH climatological aerosol data for the corresponding GFDL climatological aerosol data in Model A resulted in a modest change, of order -5 W m^{-2}, between the results provided within the Aqua 1B and Aqua 2A processing. In contrast, substituting the MATCH climatological aerosol data for the WCP-55 aerosols in Model B resulted in a substantial change, of order +40 W m^{-2}, between the results provided within the Aqua 1B and Aqua 2A processing. Preliminary studies indicated that the changes made to Models A and B should produce modest changes to the flux, similar to those actually seen in the Model A results. Thus, the extremely large flux changes to Model B results were unanticipated. Upon closer investigation, we found interdependencies within Model B which created havoc when simply substituting the MATCH aerosols for the WCP-55 aerosols. Thus, upgrading Model B to use the MATCH aerosols will require further study which should be ready before the next CERES edition. In the meantime, for Aqua 2B, we have returned the SW Model B algorithm to the same version as Aqua 1B, which uses the WCP-55 aerosols.

Downward Shortwave Model A Comparisons, Clear-Sky, 1 min data

Scene Type	# of Points	Mean Bias	RMS Difference	Standard Deviation
Continental	1345	-10.20 W m^{-2} (-1.40%)	33.97 W m^{-2} (4.06%)	32.40 W m^{-2} (4.81.%)
Desert	658	-27.50 W m^{-2} (-3.40%)	63.65 W m^{-2} (6.07%)	57.40 W m^{-2} (7.10%)
Coastal	132	0.50 W m^{-2} (0.10%)	31.80 W m^{-2} (4.60%)	31.80 W m^{-2} (4.60%)
Island	43	43.20 W m^{-2} (5.00%)	81.92 W m^{-2} (9.52%)	69.60 W m^{-2} (8.10%)
Polar	338	-45.80 W m^{-2} (-10.80%)	51.39 W m^{-2} (12.12%)	23.30 W m^{-2} (5.50%)

Downward Shortwave Model B Comparisons, Clear-Sky, 1 min data

Scene Type	# of Points	Mean Bias	RMS Difference	Standard Deviation
Continental	1351	-23.20 W m^{-2} (-3.30%)	37.69. W m^{-2} (5.34%)	29.70 W m^{-2} (4.20%)
Desert	664	-25.40 W m^{-2} (-3.10%)	50.11 W m^{-2} (6.14%)	43.20 W m^{-2} (5.30%)
Coastal	134	-2.40 W m^{-2} (-0.30%)	28.80 W m^{-2} (4.11%)	28.70 W m^{-2} (4.10%)
Island	43	26.00 W m^{-2} (3.00%)	71.68 W m^{-2} (8.36%)	66.80 W m^{-2} (7.80%)
Polar	353	-2.40 W m^{-2} (-0.60%)	13.81 W m^{-2} (3.35%)	13.60 W m^{-2} (3.30%)

All-sky Shortwave Downward Flux Validation: Model B

Results are also presented for the all-sky Model B case. To reduce the considerable variance introduced by broken cloud fields, the surface data is averaged over the 60 minutes centered on the time of the satellite overpass. Note, the variance introduced by broken cloud fields is far greater than that introduced by the temporal averaging.

As with the clear-sky cases, substituting the MATCH climatological aerosol data for the WCP-55 aerosols in Model B resulted in a substantial flux change for most cases, of order +30 W m^{-2}, between the results provided within the Aqua 1B and Aqua 2A processing. The notable exception was the Polar cases, which showed very little change to the fluxes, of order -5 W m^{-2}. As with the clear-sky cases, preliminary studies of the algorithm changes made to Model B indicated that these changes should produce only modest flux changes. Thus, the all-sky flux values calculated with Model B, just like the clear-sky values, are considered suspect. We currently anticipate an updated version of Model B to be ready before the next CERES edition. In the meantime, for Aqua 2B, we have returned the SW Model B algorithm to the same version as Aqua 1B, which uses the WCP-55 aerosols.

Downward Shortwave Model B Comparisons, All-Sky, 60 min data

Scene Type	# of Points	Mean Bias	RMS Difference	Standard Deviation
Continental	8114	20.30 W m^{-2} (3.80%)	76.83 W m^{-2} (14.51%)	74.10 W m^{-2} (14.00%)
Desert	3223	-4.90 W m^{-2} (-0.70%)	82.15 W m^{-2} (12.02%)	82.00 W m^{-2} (12.00%)
Coastal	1358	28.30 W m^{-2} (5.30%)	88.17 W m^{-2} (16.48%)	83.50 W m^{-2} (15.60%)
Island	2900	54.10 W m^{-2} (8.50%)	116.79 W m^{-2} (18.38%)	103.50 W m^{-2} (16.30%)
Polar	8837	8.30 W m^{-2} (3.30%)	67.41 W m^{-2} (27.20%)	66.90 W m^{-2} (27.00%)

Clear-sky Longwave Downward Flux Validation: Model A

Longwave Model A uses CERES-derived window and non-window TOA fluxes as well as the meteorological profiles to obtain surface fluxes for clear sky conditions. Biases are defined to be CERES derived surface fluxes minus surface measured fluxes.

Downward Longwave Model A Comparisons, Clear-Sky, 1 min data

Scene Type	# of Points	Mean Bias	RMS Difference	Standard Deviation
Continental	3647	-5.10 W m^{-2} (-1.80%)	14.34 W m^{-2} (4.94%)	13.40 W m^{-2} (4.60%)
Desert	1669	0.00 W m^{-2} (0.00%)	24.30 W m^{-2} (8.00%)	24.30 W m^{-2} (8.00%)
Coastal	455	5.00 W m^{-2} (1.70%)	13.84 W m^{-2} (4.81%)	12.90 W m^{-2} (4.50%)
Island	118	0.30 W m^{-2} (0.10%)	11.60 W m^{-2} (3.00%)	11.60 W m^{-2} (3.00%)
Polar	960	-15.00 W m^{-2} (-12.90%)	19.02 W m^{-2} (16.32%)	11.70 W m^{-2} (10.00%)

Theoretical studies and validation studies employing data from Central Equatorial Pacific Experiment (CEPEX), reported by Inamdar and Ramanathan (1997), are consistent with our results. The parameterization over land surfaces was initially developed using a limited set of emissivity data available from IRIS measurements aboard NIMBUS 4 (Prabhakara and Dalu 1976). The current version of longwave Model A, however, was developed using the global emissivity maps developed by Wilber et al. (1999) and thus can be applied to the extra-tropics as well as to the tropics. Other possible sources of errors include:

1. Specification of the true radiating temperature (especially land surfaces);
2. Errors in scene identification;
3. Emissions from aerosols in the boundary layer. For instance, Inamdar and Ramanathan (1997) noted that sensitivity studies had revealed that thick haze in the boundary layer (visibilities less than 15 km) could increase the downward emissions by about 3 - 5 W m^{-2}.

All-sky Longwave Downward Flux Validation: Model B

Longwave Model B uses the meteorological profiles and CERES MODIS-derived cloud properties, but not the CERES-derived TOA fluxes, to obtain surface fluxes for clear and all-sky conditions. Biases are defined to be CERES derived surface fluxes minus surface measured fluxes.

Model B has recently been modified to handle clouds more precisely for cases where the cloud base pressures have not been specified over high altitude areas, such as Tibet. Although important for some cases, this modification has no impact on the results provided in this document since none of our validation sites are located at such high altitudes.

Downward Longwave Model B Comparisons, Clear-Sky, 1 min data

Scene Type	# of Points	Mean Bias	RMS Difference	Standard Deviation
Continental	3663	-8.00 W m^{-2} (-2.80%)	15.35 W m^{-2} (5.30%)	13.10 W m^{-2} (4.50%)
Desert	1681	-4.00 W m^{-2} (-1.30%)	23.05 W m^{-2} (7.51%)	22.70 W m^{-2} (7.40%)
Coastal	460	-0.20 W m^{-2} (-0.10%)	13.40 W m^{-2} (4.70%)	13.40 W m^{-2} (4.70%)
Island	119	2.50 W m^{-2} (0.60%)	13.53 W m^{-2} (3.45%)	13.30 W m^{-2} (3.40%)
Polar	972	-8.80 W m^{-2} (-7.50%)	14.32 W m^{-2} (12.26%)	11.30 W m^{-2} (9.70%)

Downward Longwave Model B Comparisons, All-Sky, 1 min data

Scene Type	# of Points	Mean Bias	RMS Difference	Standard Deviation
Continental	16475	-4.80 W m^{-2} (-1.50%)	20.47 W m^{-2} (6.48%)	19.90 W m^{-2} (6.30%)
Desert	5812	5.10 W m^{-2} (1.60%)	29.15 W m^{-2} (9.04%)	28.70 W m^{-2} (8.90%)
Coastal	2748	4.20 W m^{-2} (1.20%)	21.91 W m^{-2} (6.51%)	21.50 W m^{-2} (6.40%)
Island	5819	5.40 W m^{-2} (1.30%)	15.75 W m^{-2} (3.83%)	14.80 W m^{-2} (3.60%)
Polar	19727	-8.10 W m^{-2} (-3.80%)	28.09 W m^{-2} (13.06%)	26.90 W m^{-2} (12.50%)

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